User Manual

Allen-Bradley

DriveGuard®

Safe Torque Off Option for PowerFlex 700S Phase II AC Drives and PowerFlex 700L Liquid-Cooled AC Drives

Catalog Number 20D-P2-DG01

Original Instructions

Allen-Bradley • Rockwell Software

Rockwell Automation

Important User Information

Solid state equipment has operational characteristics differing from those of electromechanical equipment. Safety Guidelines for the Application, Installation and Maintenance of Solid State Controls (Publication SGI-1.1 available from your local Rockwell Automation sales office or online at http://www.rockwellautomation.com/literature/) describes some important differences between solid-state equipment and hard-wired electromechanical devices. Because of this difference, and also because of the wide variety of uses for solid state equipment, all persons responsible for applying this equipment must satisfy themselves that each intended application of this equipment is acceptable.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

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Throughout this manual, when necessary we use notes to make you aware of safety considerations.

	WARNING: Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.
	ATTENTION: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequences.
	SHOCK HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.
	BURN HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.
IMPORTANT	Identifies information that is critical for successful application and understanding of the product.

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This manual contains new and updated information.

New and Updated Information

The following changes apply to this revision of the manual.

Change	See Page…
Added "Original Instructions" to the front cover.	–
Updated the Important statement regarding the proper use of the Safe Torque Off option.	7
Updated the information in the Evaluation/Certification by TÜV Rheinland Group table to support frame 5 and 6 and frames 9…14 drives.	9
Updated the information in the PFD and PFH for 20-year Proof Test Interval table to support frame 9…14 drives.	12
Added steps for installing the Safe Torque Off option board in frame 9…14 drives.	17
Added frames 9…14 drives to wiring diagram example 2.	32

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General Description

The DriveGuard Safe Torque Off option, when used with other safety components, helps provide protection to meet the requirements for SIL CL2 and Category 3 or PL d class applications. Safety requirements are based on the standards current at the time of certification.

The DriveGuard Safe Torque Off option is just one component in a safety control system. Components in the system must be chosen and applied appropriately to achieve the desired level of operator safeguarding.

What Is the DriveGuard Safe Torque Off Option?

The DriveGuard Safe Torque Off option:

- Is designed to help safely remove power from the gate firing circuits of the drive's output power devices (IGBT's). This helps prevent the drive's output power devices from switching in the pattern necessary to generate rotation at the motor.
- Can be used in combination with other safety devices to satisfy the Safe Torque Off requirements of SIL CL2, according to EN 61800-5-2, IEC 61508, and EN 62061 Performance Level PL d and Category 3 according to EN ISO 13849-1.

IMPORTANT This option is suitable for performing mechanical work on the drive system or affected area of a machine only. It does not provide electrical safety. For electrical maintenance on the drive and/or motor, equipment must be electrically disconnected from the power source.

The Safe Torque Off option should not be used for non safety-related stopping of the drive.

ATTENTION: Electrical Shock Hazard. Verify that all sources of AC and DC power are de-energized and locked out or tagged out in accordance with the requirements of ANSI/NFPA 70E, Part II.

ATTENTION: To avoid an electric shock hazard, verify that the voltage on the bus capacitors has discharged before performing any work on the drive. Measure the DC bus voltage at the +DC and -DC terminals or test points (refer to your drive's *User Manual* for locations). The voltage must be zero.

ATTENTION: In Safe Torque Off mode, hazardous voltages may still be present at the motor. To avoid an electric shock hazard, disconnect power to the motor and verify that the voltage is zero before performing any work on the motor.

ATTENTION: In the event of the failure of two output IGBTs in the drive, when the DriveGuard Safe Torque Off option has controlled the drive outputs to the off state, the drive may provide energy for up to 180° of rotation in a 2-pole motor before torque production in the motor ceases.

Safety of Machinery Standards

The DriveGuard Safe Torque Off option meets the following council directives and the requirements of the following machine safety standards:

- EN 61800-5-2:2007 Adjustable Speed Electrical Power Drives Systems – Part 5-2 Safety Requirements: Functional
- EN ISO 13849-1:2008 Safety of Machinery – Safety-related parts of control systems - Part 1: General Principles for Design
- EN 62061:2005 Safety of Machinery, Functional safety of safety-related electrical, electronic and programmable electronic control systems
- EN 60204-1:2006 Safety of Machinery – Electrical equipment of machines – Part 1: General Requirements
- IEC 61508 Part 1-7:1998, 2000, and 2010 Functional safety of electrical / electronic / programmable electronic safety-related systems

Safety Certifications

The TÜV Rheinland group has approved the DriveGuard Safe Torque Off option for use in safety-related applications where the de-energized state is considered to be the safe state. All of the examples related to I/O included in this manual are based on achieving de-energization as the safe state for typical Machine Safety and Emergency Shutdown (ESD) systems.

Evaluation/Certification by TÜV Rheinland Group

Drive	Rating	TUV Report on Safety Function & TUV Certification
PowerFlex 700S Phase II	208/240V and 400/480V Frames 1…6	TUV Certificate No. 01/205/5195/12 TUV Report No. 968/EZ 189.01/09
	600/690V Frames 5 and 6	
	400/480V and 600/690V Frames 9…14	TUV Certificate No. 01/205/5195/12 TUV Report No. 968/EZ 189.02/12
PowerFlex 700L Liquid-Cooled	400/480V and 600/690V Frames 3A and 3B	TUV Report and Certificate No. 968/EZ 230.00/06 TUV Certificate No. 01/205/0667/09 TUV Report No. 968/EZ 230.02/09

Certifications Online

See the Product Certifications link at http://ab.com for Declarations of Conformity, Certificates, and other certifications details.

Important Safety Considerations

The system user is responsible for:

- the set-up, safety rating, and validation of any sensors or actuators connected to the system.
- completing a system-level risk assessment and reassessing the system any time a change is made.
- certification of the system to the desired safety performance level.
- project management and proof testing.
- programming the application software and the safety option configurations in accordance with the information in this manual.
- access control to the system, including password handling.
- analyzing all configuration settings and choosing the proper setting to achieve the required safety rating.

IMPORTANT When applying Functional Safety, restrict access to qualified, authorized personnel who are trained and experienced.

ATTENTION: When designing your system, consider how personnel will exit the machine if the door locks while they are in the machine. Additional safeguarding devices may be required for your specific application.

Safety Category 3 Performance Definition

To achieve Safety Category 3 according to EN ISO 13849-1:2008, the safety-related parts have to be designed such that:

- the safety-related parts of machine control systems and/or their protective equipment, as well as their components, shall be designed, constructed, selected, assembled, and combined in accordance with relevant standards so that they can withstand expected conditions.
- well tried safety principles shall be applied.
- a single fault in any of its parts does not lead to a loss of safety function.
- some but not all faults will be detected.
- the accumulation of undetected faults can lead to loss of safety function.
- short circuits in the external wiring of the safety inputs is not one of the faults that can be detected by the system, therefore, according to DIN EN ISO 13549-2, these cables must be installed so as to be protected against external damage by cable ducting or armor.

Stop Category Definitions

The selection of a stop category for each stop function must be determined by a risk assessment.

- Stop Category 0 is achieved with immediate removal of power to the actuator, resulting in an uncontrolled coast to stop. See "Description of Operation" Example 1 on page 31 and Example 2 on page 32.
- Stop Category 1 is achieved with power available to the machine actuators to achieve the stop. Power is removed from the actuators when the stop is achieved. See "Description of Operation" Example 3 on page 33.

IMPORTANT When designing the machine application, timing and distance should be considered for a coast to stop (Stop Category 0 or Safe Torque Off). For more information regarding stop categories, refer to EN 60204-1.

Performance Level and Safety Integrity Level (SIL) CL2

For safety-related control systems, Performance Level (PL), according to EN ISO 13849-1, and SIL levels, according to IEC 61508 and EN 62061, include a rating of the system's ability to perform its safety functions. All of the safety-related components of the control system must be included in both a risk assessment and the determination of the achieved levels.

Refer to the EN ISO 13849-1, IEC 61508, and EN 62061 standards for complete information on requirements for PL and SIL determination.

PFD and PFH Definitions

Safety-related systems can be classified as operating in either a Low Demand mode, or in a High Demand/Continuous mode.

- Low Demand mode: where the frequency of demands for operation made on a safety-related system is no greater than one per year or no greater than twice the proof-test frequency.
- High Demand/Continuous mode: where the frequency of demands for operation made on a safety-related system is greater than once per year or greater than twice the proof test interval.

The SIL value for a Low Demand safety-related system is directly related to order-of-magnitude ranges of its average probability of failure to satisfactorily perform its safety function on demand or, simply, average probability of failure on demand (PFD). The SIL value for a High Demand/Continuous mode safety-related system is directly related to the probability of a dangerous failure occurring per hour (PFH).

PFD and PFH Data

These PFD and PFH calculations are based on the equations from Part 6 of IEC 61508 and show worst-case values.

This table provides data for a 20-year proof test interval and demonstrates the worst-case effect of various configuration changes on the data.

PFD and PFH for 20-year Proof Test Interval

Attribute	Test Result Frames 1…6	Test Result Frames 9…14
PFD_{av}	5.28×10^{-5}	2.14×10^{-4}
PFH	6.00×10^{-10} 1/h (calculated according to IEC 61508)	2.64×10^{-9} 1/h (calculated according to IEC 61508)
$MTTF_D$	High (4023 years)	High (11415 years)
DC_{av}	low (69%)	low (80%)

Functional Proof Tests

The functional safety standards require that functional proof tests be performed on the equipment used in the system. Proof tests are performed at user-defined intervals and are dependent upon PFD and PFH values.

IMPORTANT Your specific application determines the time frame for the proof test interval.

Contact Information if Safety Option Failure Occurs

If you experience a failure with any safety-certified device, contact your local Rockwell Automation distributor. With this contact, you can:

- return the device to Rockwell Automation so the failure is appropriately logged for the catalog number affected and a record is made of the failure.
- request a failure analysis (if necessary) to determine the probable cause of the failure.

Notes:

Installation and Wiring

Pre-Installation Instructions

Installation must be in accordance with the following steps and must be carried out by competent personnel. The DriveGuard Safe Torque Off option is intended to be part of the safety related control system of a machine. Before installation, a risk assessment should be performed that compares the DriveGuard Safe Torque Off option specifications and all foreseeable operational and environmental characteristics of the machine to which it is to be fitted.

A safety analysis of the machine section controlled by the drive is required to determine how often the safety function should be tested for proper operation during the life of the machine.

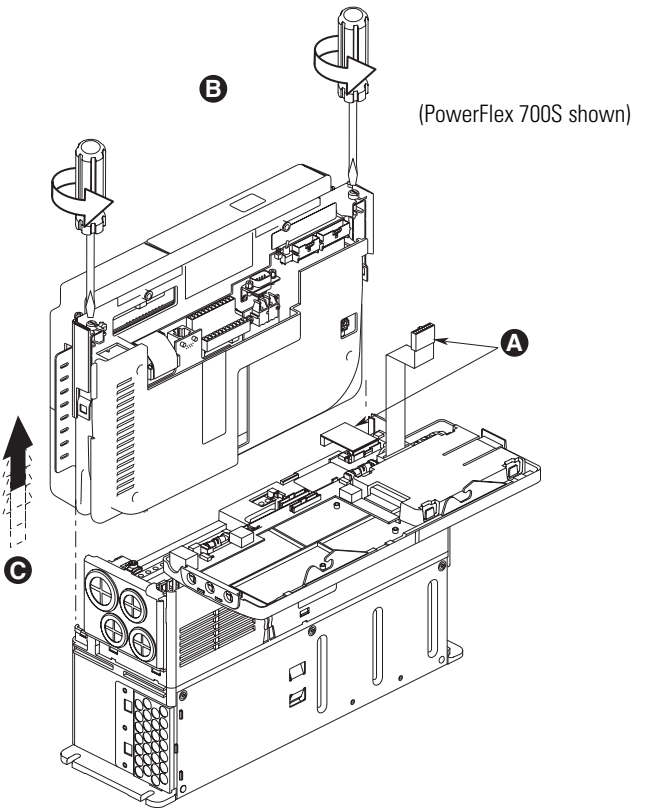
ATTENTION: The following information is merely a guide for proper installation. Rockwell Automation, Inc. cannot assume responsibility for the compliance or the noncompliance to any code, national, local or otherwise for the proper installation of this equipment. A hazard of personal injury and/or equipment damage exists if codes are ignored during installation.

Option Board Installation

PowerFlex 700S Frames 1…6 and PowerFlex 700L Frames 3A and 3B

1. Remove the I/O Control Cassette from the drive.

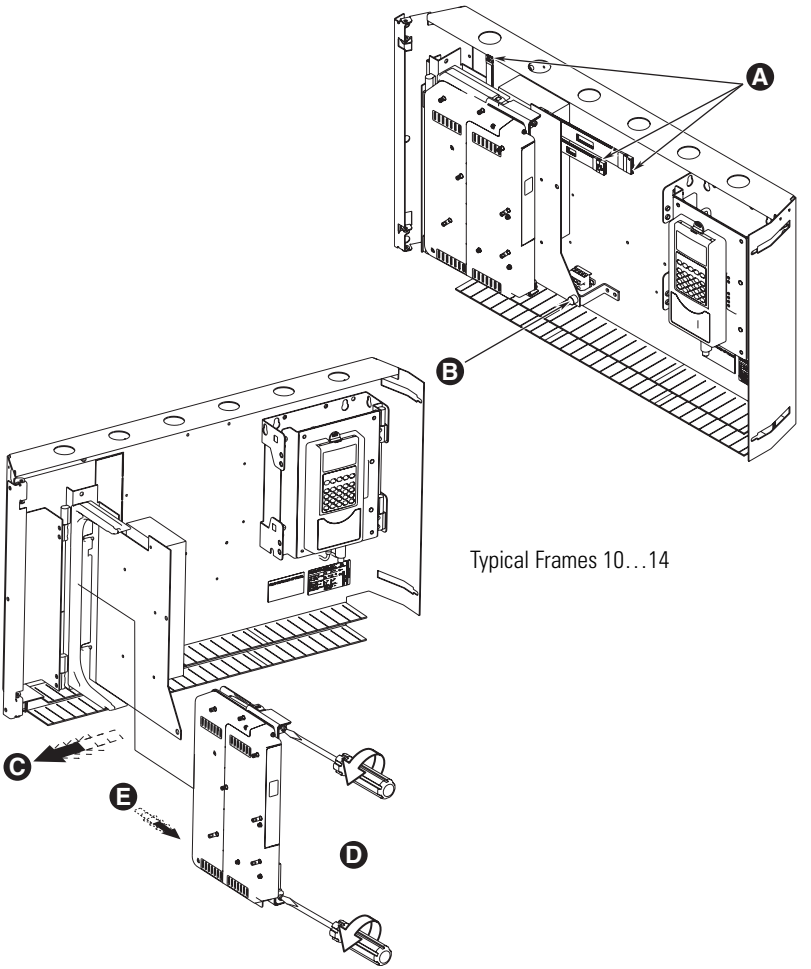
Task	Description
A	Open the door of the power structure and disconnect the cables that connect to the main board.
B	Loosen the screws on the face of the cassette.
C	Remove the cassette.



PowerFlex 700S Frames 9…14

1. Remove the I/O Control Cassette from the drive.

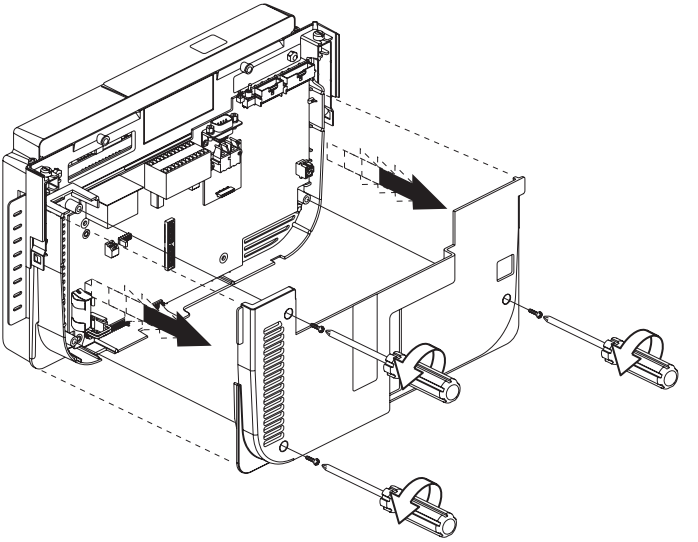
Task	Description
A	Open the door of the power structure and carefully disconnect the three cables that connect to the main board.
B	Loosen the thumb screw that holds the metal flange in place.
C	Swing the flange and cassette away from the control frame.
D	Loosen the screws on the face of the cassette.
E	Remove the cassette.



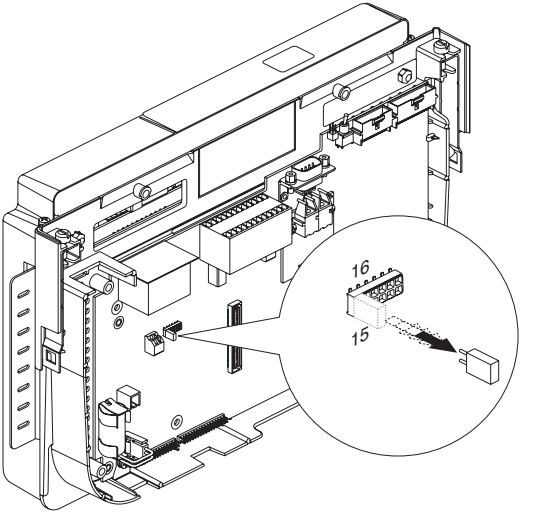
Typical Frames 10…14

PowerFlex 700S, All Frames, and PowerFlex 700L, Frame 3

2. Remove the screws securing the interior cassette cover to gain access to the Main board.

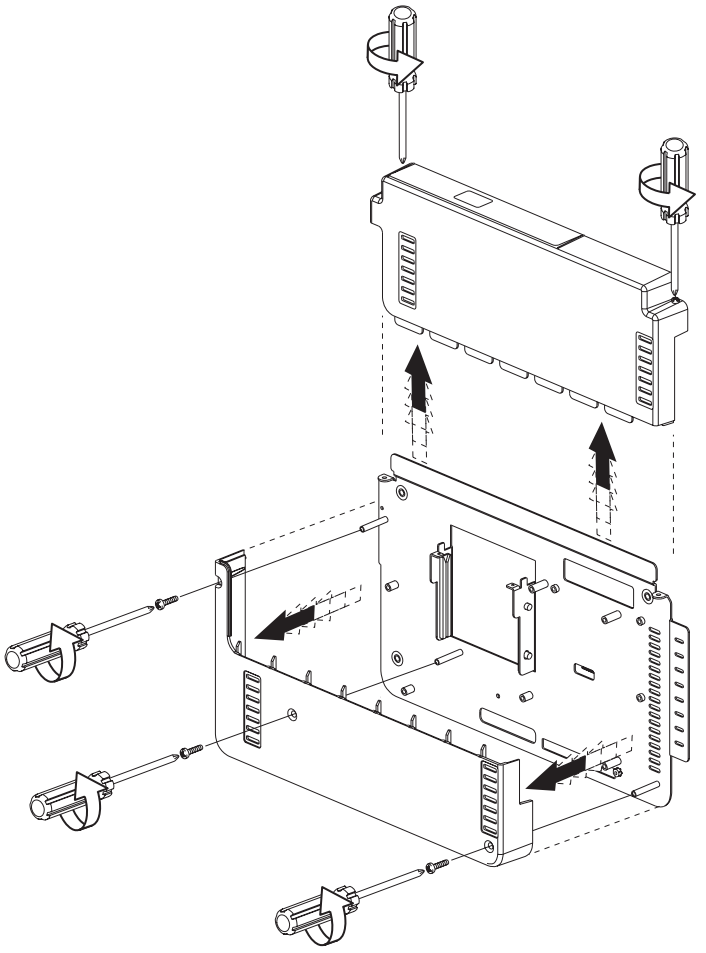


3. Remove the 2-pin shunt jumper from the 16-15 pin position.

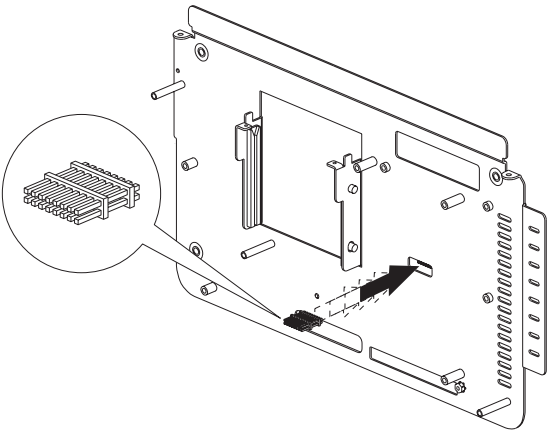


IMPORTANT If the DriveGuard Safe Torque Off option is removed from the drive, this jumper must be reinstalled or the drive will not run.

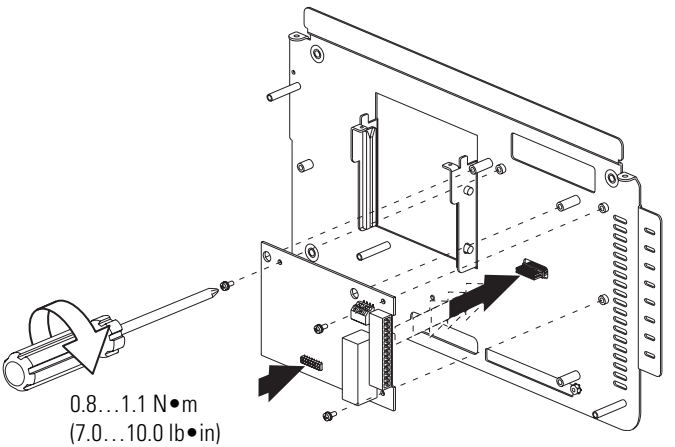
4. Remove the exterior cassette covers to access the grounding plate.



5. Install the 16-pin stacker connector.

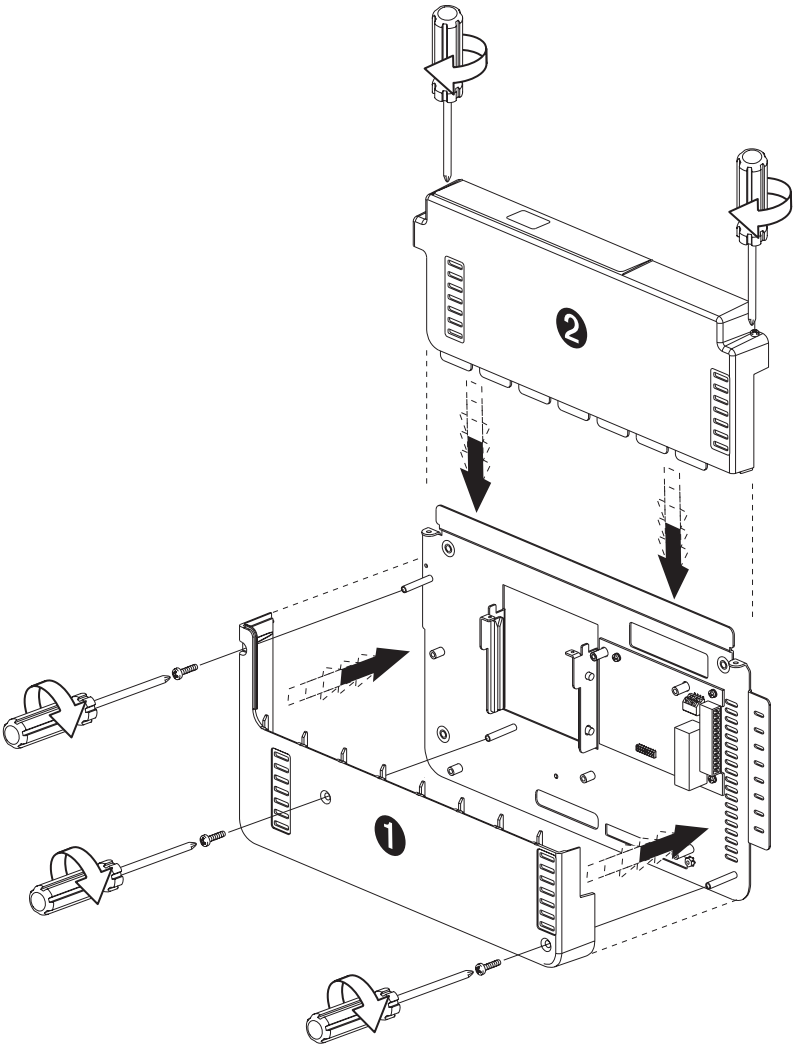


6. Plug the DriveGuard Safe Torque Off option into the 16-pin connector.

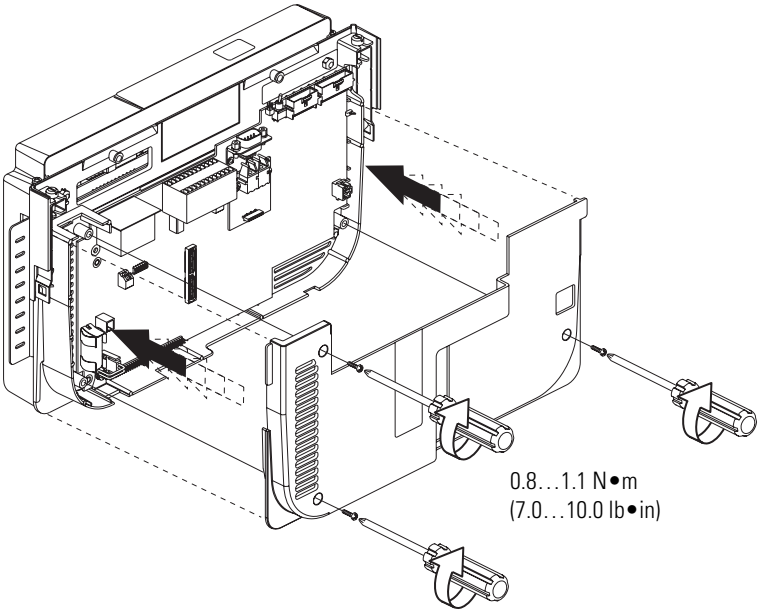


7. Install and tighten mounting screws.

8. Install the exterior cassette covers.



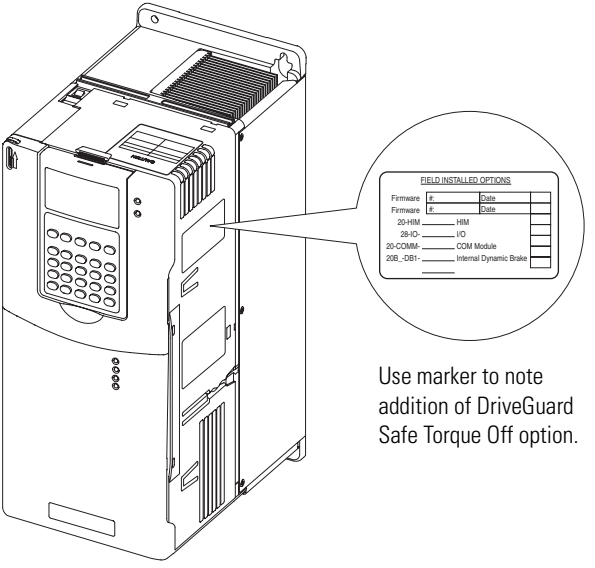
9. Install the inside front cover.



10. Reinstall the cassette in the drive.

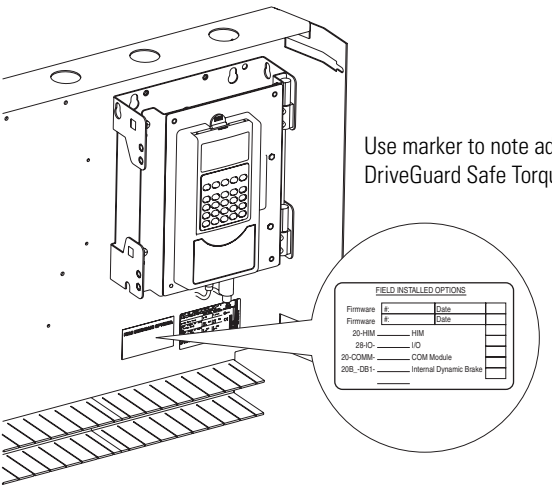
11. Record the modification on the Field Installed Option label.

PowerFlex 700S Frames 1…6



Use marker to note addition of DriveGuard Safe Torque Off option.

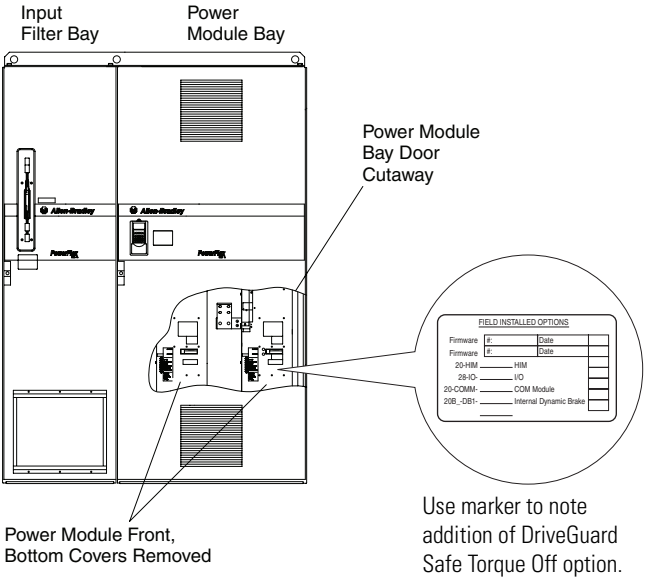
PowerFlex 700S Frames 9…14



Use marker to note addition of DriveGuard Safe Torque Off option.

(Frame 10 shown)

PowerFlex 700L Frames 3A and 3B



Wiring

Important points to remember about wiring:

- Always use tinned copper wire.
- Wire with an insulation rating of 600V or greater is recommended.
- Control wires should be separated from power wires by at least 0.3 meters (1 foot).
- All control wires should be shielded cable with the shield earthed on one end of the cable.

Table 1 - DriveGuard Safe Torque Off Option Terminal Block Specifications

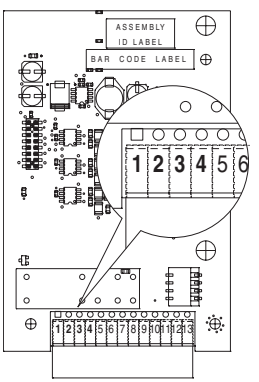
Wire Size Range(1)		Torque	
Maximum	**Minimum**	**Maximum**	**Recommended**
1.5 mm^2 (16 AWG)	0.14 mm^2 (26 AWG)	0.25 N•m (2.2 lb•in)	0.22 N•m (1.9 lb•in)

(1) Maximum / minimum that the terminal block will accept - these are not recommendations.

Table 2 - Wire Types

Wire Type(s)		Description	Minimum Insulation Rating
Unshielded	Per US NEC or applicable national or local code	NOT RECOMMENDED	300V, 60 degrees C (140 degrees F)
Shielded	Multi-conductor shielded cable such as Belden 8770(or equiv.)	0.750 mm^2(18AWG), 3 conductor, shielded.	

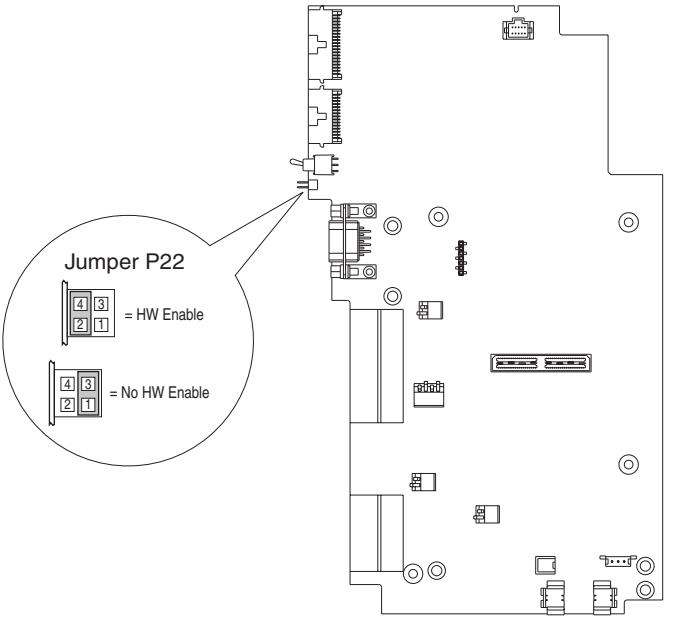
Table 3 - DriveGuard Safe Torque Off Option Terminals Description



No.	Signal	Description
1	+24V DC	Connections for user-supplied power to energize coil. 33.3 mA typical, 55 mA maximum.
2	24V Common	
3	Monitor - N.C.	Normally closed contacts for monitoring relay status. Maximum Resistive Load: 250V AC / 30V DC / 50 VA / 60 Watts Maximum Inductive Load: 250V AC / 30V DC / 25 VA / 30 Watts
4	Common - N.C.	

Configure Hardware Enable

Ensure that Jumper P22 on the Main Control Board is set to HW Enable (Pins 2 and 4).



IMPORTANT In addition to the correct jumper setting, enable circuitry must be connected to I/O Terminals 13 and 16. For wiring examples, refer to the following publications.

- PowerFlex 700S Phase II Drive Frames 1…6 Installation Instructions, publication 20D-IN024
- PowerFlex 700H and 700S Drive Frames 9…14 Installation Instructions, publication PFLEX-IN006

Configure Digital Outputs

Digital Output 1 and 2 (TB2 Terminals 3, 4, and 5) and Relay Output 3 (TB2 Terminals 6, 7, and 8) can be configured to activate external logic in the event the safety enable diagnostic routine results in an F45 "Enable Health" fault.

1. Set Par 147 [FW Functions En], Bit 14 "Digital Outs" to 1 (True).
2. Set Par 845 [Dig Out1 Sel], Par 850 [Dig Out2 Sel] or Par 855 [Rly Out3 Sel] to option 0 "User Select".
3. Link Par 846 [Dig Out1 Data], Par 851 [Dig Out2 Data] or Par 856 [Rly Out3 Data] to Par 324 [Fault Status 2]. See "Linking Parameters" below.
4. Set Par 847 [Dig Out1 Bit], Par 852 [Dig Out2 Bit] or Par 857 [Rly Out3 Bit] to 12. Par 324 Bit 12 = EnableHealth status.

Linking Parameters

Use the following procedure to establish a link between Par 846 [Dig Out1 Data], Par 851 [Dig Out2 Data] or Par 856 [Rly Out3 Data] and Par 324 [Fault Status 2].

1. Using the drive's Human Interface Module (HIM), select Parameter from the Main Menu and press the Enter key.
2. Using the HIM keypad, enter 846, 850, or 856 and press the Enter key. The parameter value screen will appear.
3. Press ALT and then View (Sel). Next, press the Up or Down Arrow to change "Present Value" to "Defined Link." Press the Enter key.
4. Press the Enter key to select the "Link" field. Using the HIM keypad, enter 324 as the Source Parameter Number and press the Enter key.

   The linked parameter can now be viewed two different ways by repeating the steps above and selecting "Preset Value" or "Define Link." If an attempt is made to edit the value of a linked parameter, "Parameter is Linked!" will be displayed, indicating that the value is coming from a source parameter and cannot be edited.

5. To remove a link, repeat the steps above and change the source parameter to zero (0).

Verify Operations

Test the safety function for proper operation after initial installation of the DriveGuard Safe Torque Off option. Retest the safety function at the intervals determined by the safety analysis described on page 15.

Verify that both safety channels are functioning according to Table 4 below.

Table 4 - Channel Operation and Verification

Safety Function Status	Drive In Safe State	Drive In Stopped State	Drive In Stopped State	Drive Able To Run
Safety Channel Operation				
Safe Torque Off Option Terminals 1 & 2	No Power Applied	Power Applied	No Power Applied	Power Applied
PowerFlex 700S/700L Enable Input	No Power Applied	No Power Applied	Power Applied	Power Applied
Description For Verification				
Safe Torque Off Option Monitor Contact Terminals 3 & 4	Closed	Open	Closed	Open
PowerFlex 700S/700L Drive Inhibits Param. 156, Bits 1 & 16	Bit 16 = 0 Bit 1 = 1	Bit 16 = 0 Bit 1 = 1	Bit 16 = 1 Bit 1 = 0	Bit 16 = 0 Bit 1 = 0

Description of Operation

DriveGuard Safe Torque Off Operation

The DriveGuard Safe Torque Off option disables the drive's output IGBT's by disconnecting the gate control power supply (see Figure 1). When used in combination with a second safety channel (the Enable input), the system satisfies the requirements of EN ISO 13849-1, PL d / Category 3 for safe turn off of torque-producing energy at the output of the drive.

IMPORTANT The DriveGuard Safe Torque Off option does not eliminate dangerous voltages at the drive output. Input power to the drive must be turned off and safety procedures followed before performing any electrical work on the drive or motor.

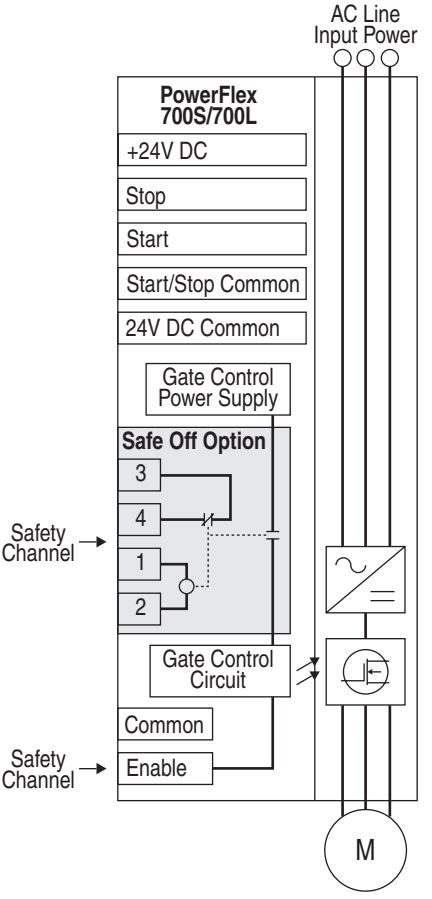
ATTENTION: In the event of the failure of two output IGBTs in the drive, when the DriveGuard Safe Torque Off option has controlled the drive outputs to the off state, the drive may provide energy for up to 180° of rotation in a 2-pole motor before torque production in the motor ceases.

Under normal drive operation, the Safe Torque Off relay is energized, the enable input is energized, and gate control power is available to the gate control circuit. If either of these inputs is de-energized, the gate control circuit is disabled and the STS (Status) indicator on the drive will change to a yellow flashing light. When the enable input is de-energized, parameter 156 [Start Inhibits], bit 1 "No Enable" is set to "1." When the Safe Torque Off relay is de-energized, parameter 156 [Start Inhibits] bit 16 "GateShutDown" is set to "1." If both inputs are de-energized, only bit 1 "No Enable" will be set to "1" because it takes precedence.

To meet EN ISO 13849-1, PL d / Category 3 operation, both safety channel inputs to the drive must be de-energized to safely turn off output to the motor. Refer to the following examples for details.

ATTENTION: By itself, the DriveGuard Safe Torque Off option initiates a coast-to-stop action. Additional protective measures will need to be applied when an application requires a different stopping action.

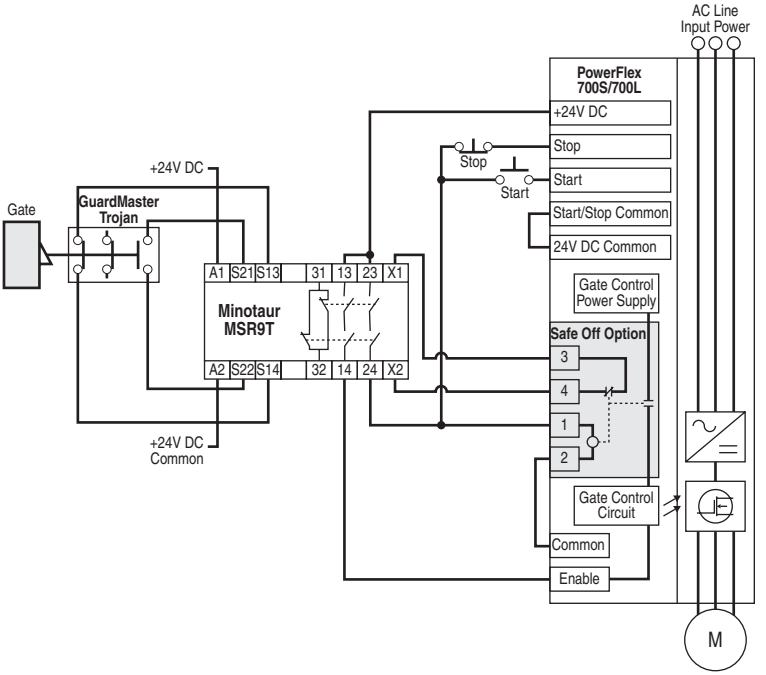
Figure 1 - Drive Safe Torque Off Circuitry



Connection Examples

Example 1 - PowerFlex 700S Drives, Frames 1…6 Safe Torque Off Connection with Coast-to-Stop Action, Dual Channel

Figure 2 - Stop Category 0 – Coast



Circuit Status

Circuit shown with guard door closed and system ready for normal drive operation.

Operating Principle

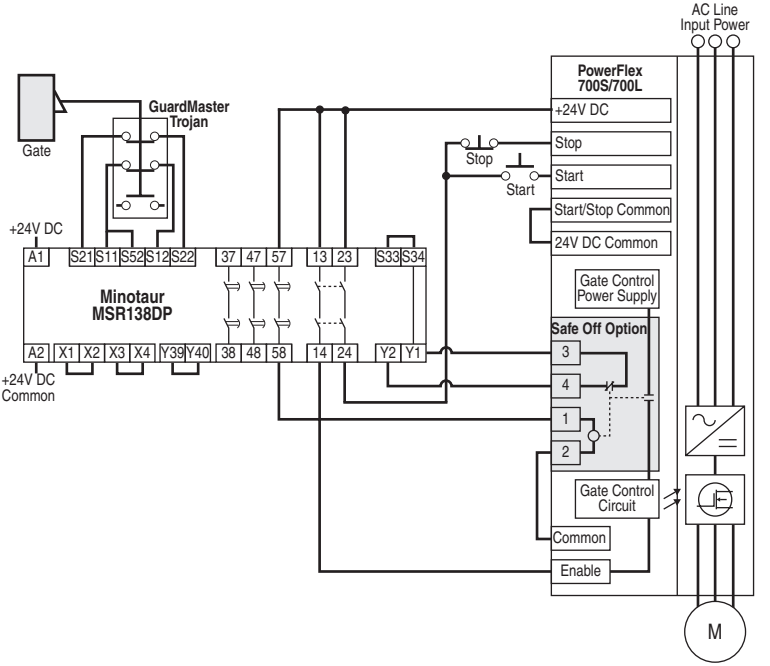
This is a dual channel system with monitoring of the Safe Torque Off circuit and drive. Opening the guard door will switch the input circuits (S13-S14 & S21-S22) to the Minotaur monitoring safety relay unit. The output circuits (13-14 & 23-24) will cause the Safe Torque Off option and drive Enable circuit to trip and the motor will coast to stop. To restart the drive, the Minotaur safety relay must first be reset followed by a valid start command to the drive.

Fault Detection

A single fault detected on the Minotaur safety input circuits will result in the lock-out of the system at the next operation and will not cause loss of the safety function.

Example 2 - PowerFlex 700S Drives, Frames 9…14 and PowerFlex 700L Drives, Frames 3A and 3B Safe Torque Off Connection with Coast-to-Stop Action, Dual Channel

Figure 3 - Stop Category 0 – Coast



Circuit Status

Circuit shown with guard door closed and system ready for normal drive operation.

Operating Principle

This is a dual channel system with monitoring of the Safe Torque Off circuit and drive. Opening the guard door will switch the input circuits (S11-S12 & S21-S22) to the Minotaur monitoring safety relay unit. The output circuits (13-14 & 23-24) cause the drive Enable circuit to trip and the motor will coast to stop. After the programmed delay, the timed output circuits (57-58) will cause the Safe Torque Off option circuit to trip. To restart the drive, the Minotaur safety relay must first be reset followed by a valid start command to the drive.

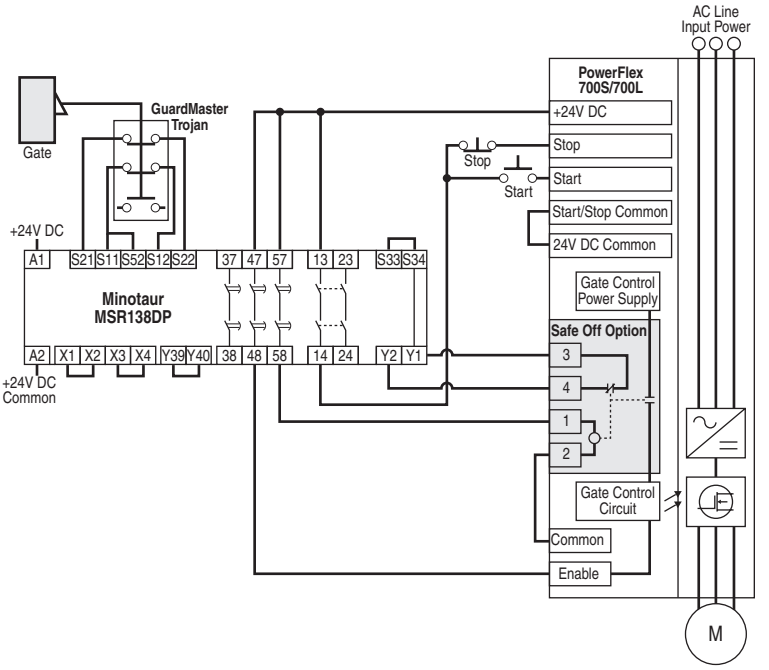
Application Considerations

When the hazard analysis for the overall machine determines the need for external mechanical brakes or other stopping means, the external means shall be activated after the removal of power for Stop Category 0.

If the Safe Torque Off option sticks ON, the motor will stop on command due to the enable input. The system cannot be reset when this fault condition exists.

Example 3 - All Drives
Safe Torque Off Connection with Controlled Stop Action, Dual Channel

Figure 4 - Stop Category 1 – Controlled



Circuit Status

Circuit shown with guard door closed and system ready for normal operation.

Operating Principle

This is a dual channel system with monitoring of the Safe Torque Off circuit and drive. Opening the guard door will switch the input circuits (S11-S12 & S21-S22) to the Minotaur monitoring safety relay unit. The output circuits (13-14) will issue a Stop command to the drive and cause a controlled deceleration. After the programmed delay, the timed output circuits (47-48 & 57-58) will cause the Safe Torque Off option and the drive Enable circuit to trip. If the motor is rotating when the trip occurs, it will coast to stop. To restart the drive, the Minotaur safety relay must first be reset followed by a valid start command to the drive.

Fault Detection

A single fault detected on the Minotaur safety input circuits will result in the lock-out of the system at the next operation and will not cause loss of the safety function.

If the Safe Torque Off option sticks ON, the motor will stop on command due to the enable input. The system cannot be reset when this fault condition exists.

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Notes:

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Publication 20D-UM007G-EN-P – March 2012
Supersedes 20D-UM007F-EN-P – September 2011
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